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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) In preliminary experiments at Seattle, electric resonances from all three isotopes of the Mg^+ ion stored in a miniaturized Paul rf trap have now been observed. In collaboration with a group at Heidelberg (not under the contract) the feasibility of our laser fluorescence observation and cooling schemes has been demonstrated on the Ba^+ mono-ion oscillator thereby cooled to $\ll 0.1K$.		

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SUMMARY

1. Principal Investigator

Hans Dehmelt

2. CONTRACT DESCRIPTION

We propose to study the interactions of atomic ions stored in a rf quadrupole trap at high vacuum with light or rf quanta.

3. SCIENTIFIC PROBLEM

We are attempting to prove the usefulness of a single suitable atomic ion brought to rest in free space as an ultimate optical frequency and time standard.

4. SCIENTIFIC AND TECHNICAL APPROACH

An individual Th^+ ion in a miniaturized rf trap will be irradiated with focused resonant laser light. This will allow us to observe and also cool the ion. Another (forbidden) line of the ion serves as the proposed standard. Associated transitions leading to a metastable level are signaled by the temporary suppression of the strong resonance fluorescence.

5. PROGRESS

In preliminary experiments at Seattle, electric resonances from all three isotopes of the Mg^+ ion stored in a miniaturized Paul rf trap have now been observed. In collaboration with a group at Heidelberg (not under the contract) the feasibility of our laser fluorescence observation and cooling schemes has been demonstrated on the Ba^+ mono-ion oscillator thereby cooled to $\ll 0.1\text{K}$.

6. PUBLICATIONS

Neuhauser et al., "Visible Localized Ba^+ Mono-ion Oscillator,"

submitted to Physical Review. (Not supported by ONR.)

8. REMAINING FUNDS

No funds are expected to remain at the end of the original contract period.

10. SUPPORT FROM OTHER AGENCIES

NSF Grant PHY 78-08562, shared with R.S. Van Dyck, Jr.

"Single Atomic Particles at Rest in Space (SAPARIS)" \$95,900 for the period 5/1/80 to 8/31/81. Supports work on e^+/e^- magnetic moments (Geonium spectra).

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ACCOMPLISHMENTS MARCH 1979 - APRIL 1980

Our apparatus designed to confine Mg^+ ions in a Paul rf trap and detect them electronically and optically has been refined. Electric resonance signals due to the $Mg^{24,25,26}$ isotopes of relative abundance of 79%, 10%, and 11% have now been resolved, see Figure A. As in the absence of a strong cooling 2803 Å laser beam it is necessary to turn off the pumps and introduce He-Buffer gas at $\sim 10^{-4}$ Torr to hold the Mg^+ ions in the trap, problems have been encountered with impurity ions such as CO^+ , COH^+ (Mass 28, 29) crowding out the Mg^+ ions of interest. This necessitated a more careful study of the masses of the ions in the trap which has now been accomplished. We ascribe the fact that the Mass 25 signal is much larger than $\sim 1/8$ of the Mass 24 signal to a now much smaller residual (tolerable) contamination of MgH^+ ions. Attempts at optical detection will soon be renewed. It is our impression that the about three times greater support level and equipment pool of the Heidelberg group (Neuhauser, Hohenstatt, Toschek and Dehmelt), had much to do with their success with the Ba^+ Mono-ion Oscillator, see Figures 1, 2, and 3. Our work at Seattle would be greatly facilitated if we had a more powerful 2803 Å laser beam available. Currently we use a frequency doubled Dye-laser pumped by a weak Argon-ion laser (borrowed) which may be recalled any day.

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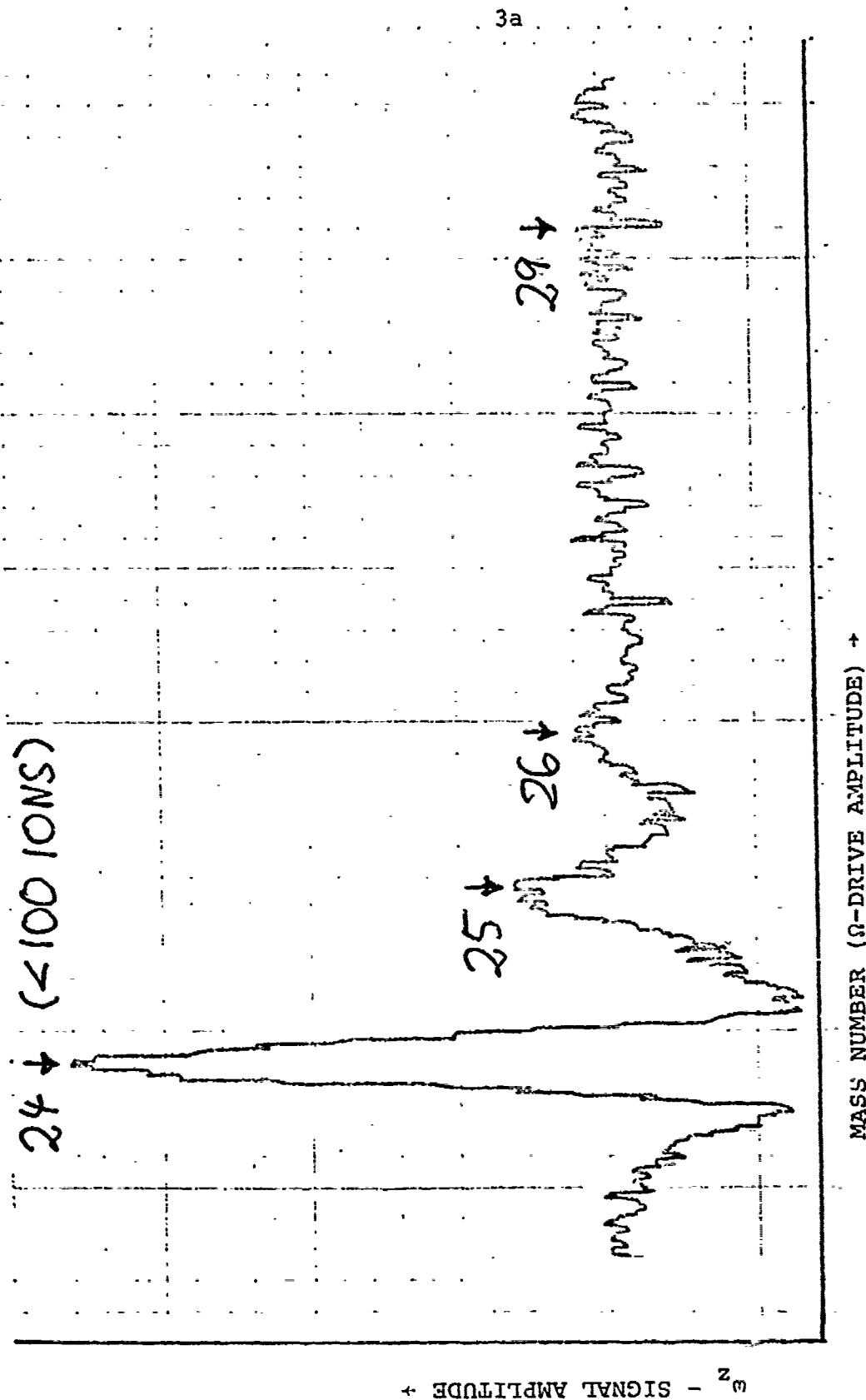


FIG. A. MASS SPECTRUM OBTAINED WITH MINIATURE rf QUADRUPOLE TRAP (CAP-SEPARATION 1.5 mm). TO OBTAIN GOOD RESOLUTION OPERATION WITH VERY FEW IONS AND $\sim 10^{-4}$ TORR He BUFFER GAS COOLING WAS NECESSARY.

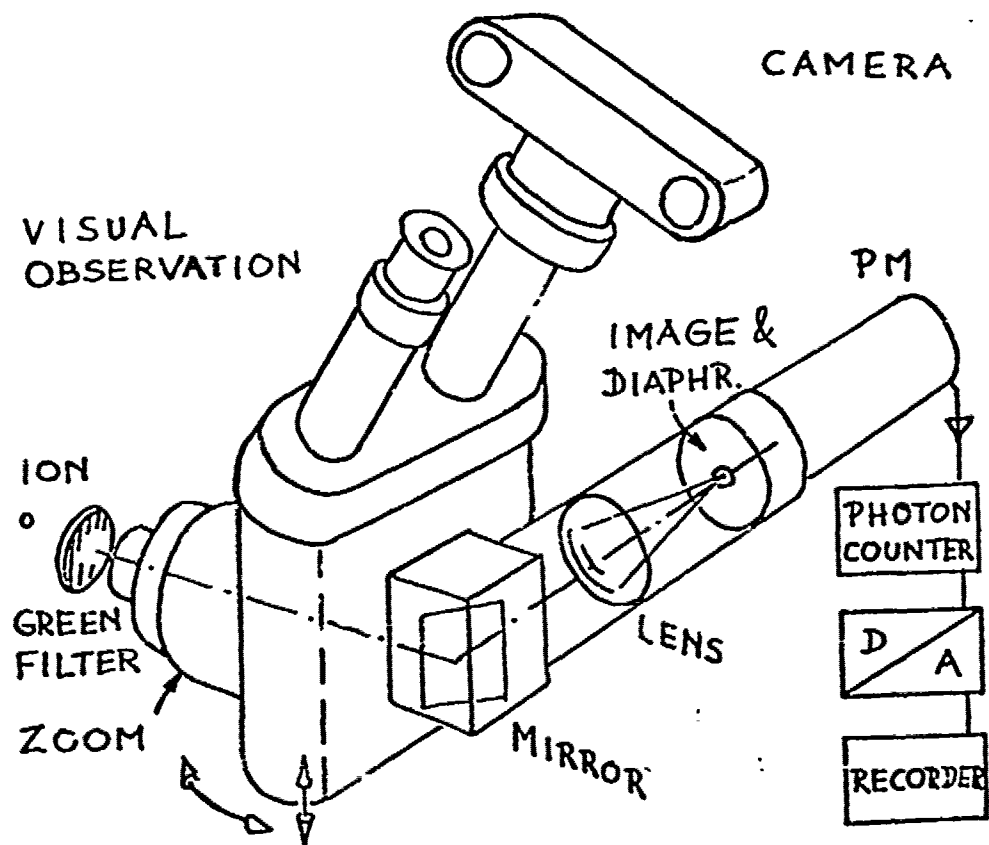


FIG. 1. OBSERVATION OPTICS EMPLOYING BINOCULAR MICROSCOPE. THE OPTICS ALLOWED SIMULTANEOUS VISUAL, PHOTOGRAPHIC, AND PHOTOELECTRIC OBSERVATION OF THE STORED IONS. FOR A SINGLE ION THE PHOTON COUNTING RATE WAS $\sim 10^4/\text{SEC}$.

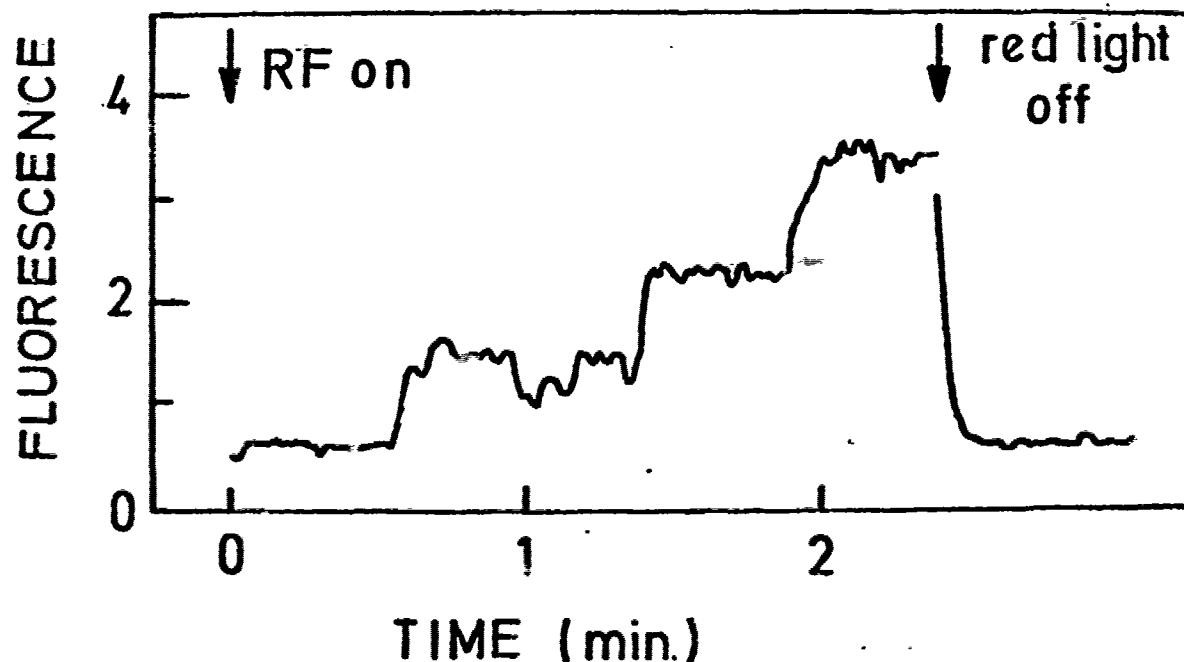


FIG. 2. Ba^+ FLUORESCENCE (ARBITRARY UNITS) VS. TIME. WITH BOTH ELECTRON AND Ba -BEAMS ON IN ULTRA-HIGH VACUUM THE TRAPPING rf POTENTIAL AT Ω WAS SWITCHED ON AT ZERO TIME. WE ASCRIBE THE THREE STEPS VISIBLE TO THE CONSECUTIVE CAPTURING OF 3 BARIUM IONS, PRESUMABLY ISOTOPES 138 OR 136, IN THE TRAP. WE ATTRIBUTE THE DROP IN THE FLUORESCENCE BY $\sim \frac{1}{2}$ UNIT IN THE ~ 15 SEC TIME INTERVAL STARTING AT ~ 1 MIN TO COLLISIONAL HEATING TO SUCH A DEGREE THAT THE IMAGE OF THE ION CLOUD EXPANDED BEYOND THE OPENING OF THE LIMITING DIAPHRAGM (FIG. 1), THE PRESUMABLE CAUSE BEING THE TEMPORARY CAPTURE OF A SECOND NON-COOLED ENERGETIC ODD Ba^+ ISOTOPE. THE ZERO-POINT DRIFT MEASURED AFTER ~ 4 MIN WAS $< .2$ UNITS. NOTE THE SMALL BACKGROUND SCATTERING OF $< \frac{1}{2}$ UNITS!

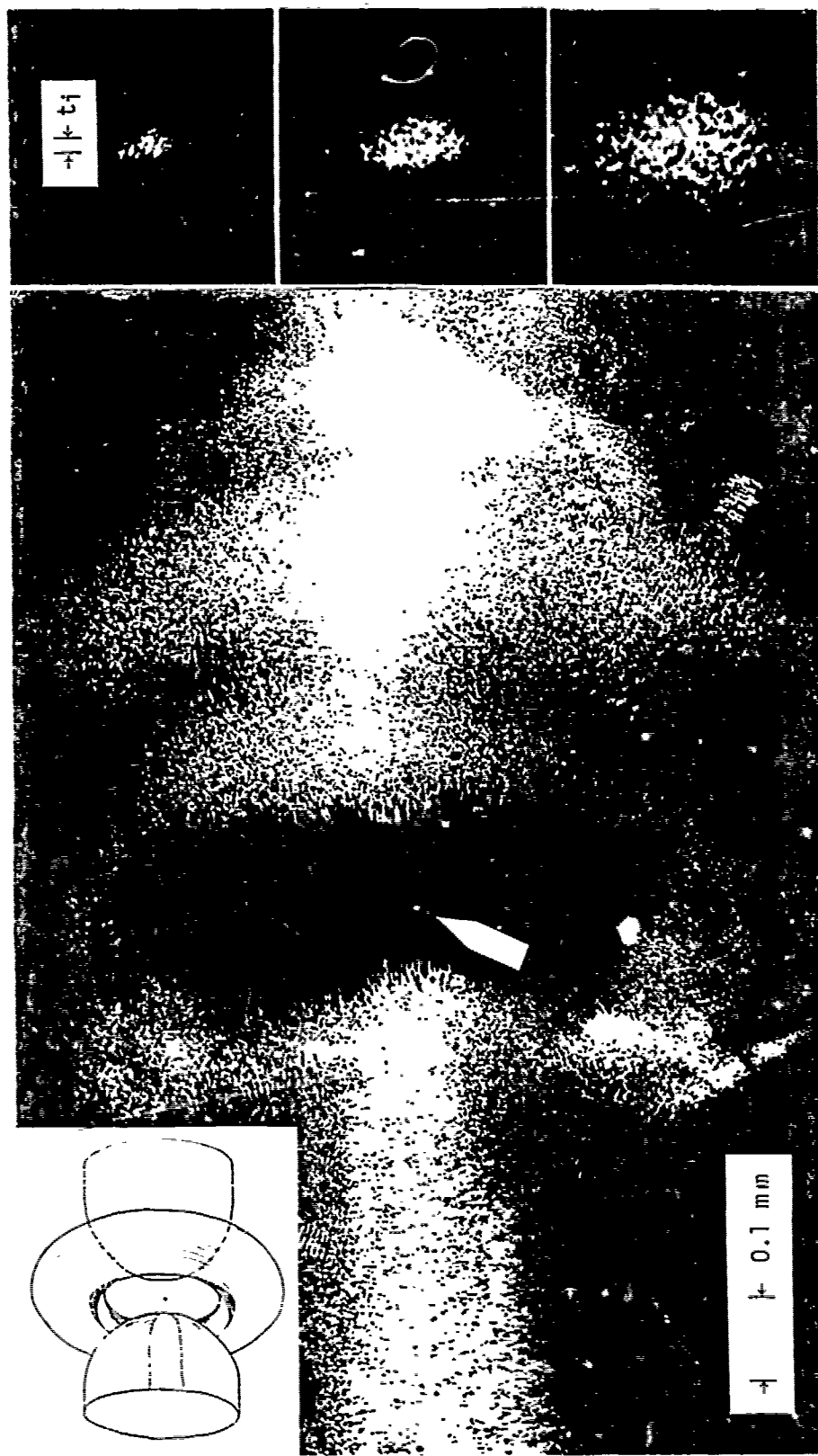


FIG. 3. MICRO-PHOTOGRAPHIC IMAGES OF 1, 2, and 3 TRAPPED Ba^+ IONS. THE LARGE PHOTOGRAPH SHOWS THE $\sim 2\mu\text{m}$ THICK IMAGE (WHITE ARROW) OF A SINGLE ION INSIDE THE rf QUADRUPOLE TRAP AS VIEWED THROUGH THE GAP BETWEEN THE RING AND THE LEFT CAP-ELECTRODES (TRAP STRUCTURE ILLUMINATED BY SCATTERED LASER LIGHT). A SKETCH OF THE WHOLE TRAP STRUCTURE SEEN FROM THE SAME ANGLE IS INSERTED. THE THREE SMALL PHOTOS, GOING FROM TOP TO BOTTOM, SHOW, 10-FOLD ENLARGED, THE CENTRAL TRAP REGION, CONTAINING 1, 2, AND 3 IONS. THE TRAP PARAMETERS WERE $\Omega = 2\pi \cdot 43.7 \text{ MHz}$, $\omega_{\text{wz}} = 2\pi \cdot 1.61 \text{ MHz}$, ELECTRON BEAM OFF, AND Ba BEAM ON. AN EXPOSURE OF 10 MIN AND KODAK 103a-F FILM WERE USED THROUGHOUT.